Conceptual Design and Options Considered

Including Budget and Timeline

REM Sleep Monitor II

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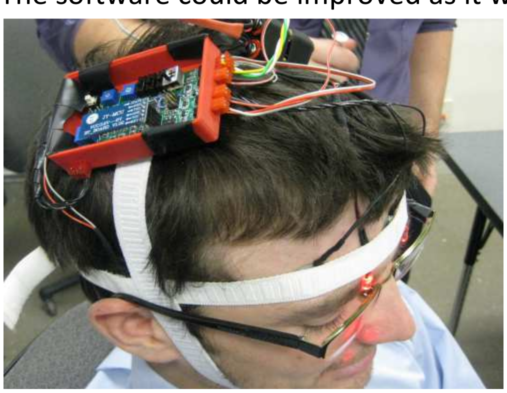
Introduction:

This monitor will detect REM sleep using EEG signals. Once REM is detected, the device will communicate this to the user to help the user make sense of the dream experience. The device will send a signal to the user while they are dreaming to induce lucid dreaming, as well as send a signal to the user directly after REM sleep. This type of device can open the door to many sleep research opportunities. Currently, EEG monitors are very expensive, reducing the amount of potential clients. Unlike other EEG monitors, our device would be much more cost effective, dare say cheap. The schematic of this device will be available on the internet so anyone can recreate it. This device could help psychologists to analyze their client's dream patterns. It could even help young children who deal with night terrors. Another possibility for the device could be for one interested in lucid dreaming as a leisure activity.

Previous Work:

REM Sleep Monitor I

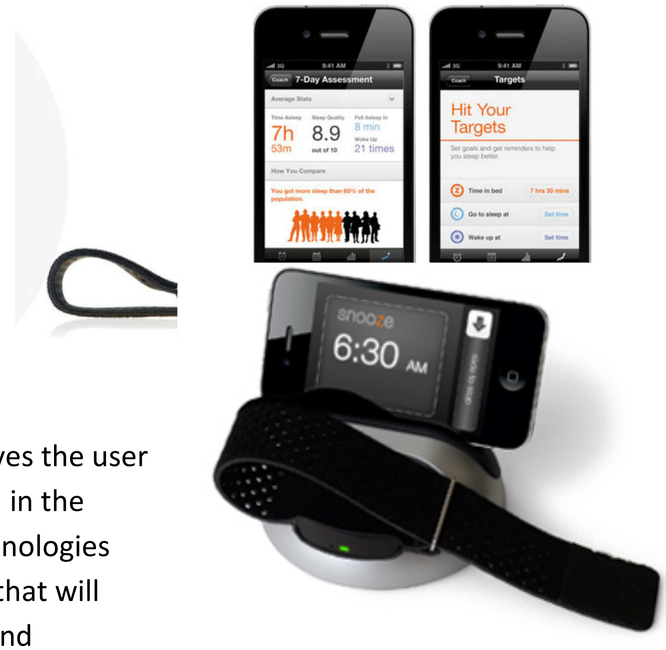
The objective of our senior design project is to continue and improve upon the REM Sleep Monitor previously developed by a past senior design team. The monitor was built as a single channel EEG/EOG monitoring device created by Pete Kronberg, Huy Ha, Garrett Nelson and Cole Teske, under the advisement of Dr. Ivan Lima. Their device was used to alert and or wake the user via motor signals located on the head. By the end of the yearlong project, there were still many things that had to be improved upon in order to continue this project toward the human research process. The team struggled to interpret detected signals of REM sleep, which were sent to the computer via Bluetooth. The hardware was sufficient, yet not all necessary. The headband contained the electrodes, the motors and the actual device. The figure below shows the device on a human subject. The headband was made of Velcro, allowing different sized head users. The software could be improved as it was not completely finished or tested.



Lark Technologies

Patent pending

Lark Technologies is the leader in sleep monitor systems for personal use. They have a variety of monitoring equipment ranging anywhere from exercising to sleeping. The latest product they have is the Lark Pro, which monitors stages of sleep and keeps a record of sleep stages throughout the night.



Lark Pro has a wrist band that monitors the sleeping stages and vibrates to gently wake the user during the lightest stage of sleep. This product gives the user a more natural way to wake up making them less tired in the morning. The second and older product that Lark Technologies has is called Lark. Lark is a silent vibrating alarm clock that will not wake the person next to you. The Lark measures and analyzes the users sleep to make sure it wakes them up during their lightest sleep period [1]. Many products follow this same concept such as the Sleeptracker.

Innovative Sleep Solutions

Pub. N0.: US 2012/0313773 A1

Sleeptracker Elite, $149 [8]

Innovative Sleep Solutions designed a product that acts as an everyday watch and more. The Sleeptracker is worn on the wrist and monitors sleep stages throughout the night. The user programs a window wake up time and the Sleeptracker constantly watches for an ideal time to wake the user. The Sleeptracker wakes the person during the lightest period of sleep via vibrator or a chime sound. Like the Lark products, the Sleeptracker follows the same concept of being awoken during lighter sleep stages which will make the user less tired in the morning. The Sleeptracker also records how many hours of sleep the user had during every use [2]. This feature makes it similar to the Zeo Sleep Managers but not as advanced as the Zeo Sleep Manager.

Zeo

Zeo Sleep Manager Pro, $160 [9]

Patent Pending

Zeo designed a product called the Zeo Sleep Manager. This product interfaces with the user's smart phone or any similar device. The Zeo Sleep Manager uses a headband to monitor EEG waves on the user. All information gathered is transmitted wirelessly to a receiver which collects and analyzes all the signals. This device comes with application that shows all the information gathered from times woken up to the amount of time in each different sleep stage. From all the information gathered the application gives the user a sleep score, which is a combination of all the data into one number [3]. Like all the other products this has a similar monitor system for sleep stages, but it does not have the alarm feature.

Lucid Dream Induction Devices

Patent N0.:US 8,267,851 B1

Dreamstar- Lucid Dream Induction Device $330 [10]


REM Dreamer Lucid Dreaming Induction Device, $239.95 [11]

Many sleep devices are used for the medical purpose of getting more sleep but a lucid dream Induction device is used for recreation. The purpose of a Lucid Dream Induction Device is to give the user the ability to control their dreams. This is done by using cues to notify the user they are dreaming. There is a variety of cues performed by LED's, motors and speakers. The REM Dreamer Lucid Dreaming Induction Device by REM

Dreamer uses infrared sensors to detect when the user is in REM sleep [4]. Once the user is in REM sleep, the device beeps and flashes lights to remind the user they are dreaming. This device has presets to customize sounds, flashes, volume, brilliance, frequency per second and duration. There are many similar devices such as the Lucid Dream Induction Device by Dreamstar. Each Lucid Dream Induction Device uses has the same process, it alerts the user when they are in the REM sleep stage [5]. The only difference between each Lucid Dream Induction Device is the type of cues and settings.

Design Options:

Microcontroller: ATmega328

Roboduino/Arduino UNO 2011 ATmega328

Features :

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	16 KB (ATmega168) or 32 KB (ATmega328) of which 2 used by bootloader
SRAM	1 KB (ATmega168) or 2 KB (ATmega328)
EEPROM	512 bytes (ATmega168) or 1 KB (ATmega328)
Clock Speed	16 MHz

Advantages: The previous group used the ATmega328 microcontroller in their design. It would be advantageous to use this microcontroller since we are continuing their project, and our group is familiar with C programming language. If we use this microcontroller we will not have to reprogram their previous work, and we can continue their code from where they left off. Changing microcontrollers could affect other aspects of the design, and be too time consuming.

Disadvantages: None of our group members have had experience with the ATmega328 microcontroller; however, Dr. Lima is familiar with this microcontroller.

Method of Powering: Wall outlet

Advantages:

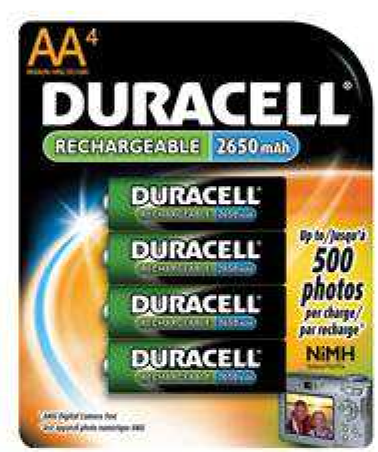
- Nearly unlimited amount of power available
- Never have to recharge/replace batteries

Disadvantages:

- Potentially dangerous to the user; risk of electrical shock
- Inconvenient if the user is not near a wall outlet
- Additional cords could be a hazard to the user

Method of Powering: Battery Power

Duracell C1500B4N AA NiMH 2650mAh 1.2-1.5V Rechargeable Batteries



Advantages:

- User safety from electrical shock ensured with battery operation
- Mobile; no external wires to wall outlet required
- Rechargeable

Disadvantages:

- Limited battery life, must recharge/replace batteries
- Limited power supply
- Purchase of batteries add to total cost

Our device will be battery powered due to safety concerns. The previous group found that 2000mAh was sufficient to power the monitor. The AA Duracell batteries we found surpass our charge requirement, and are rechargeable to reduce future costs. The device will require 4 of the 1.5V batteries, which will cost approximately $10.00.

Headband: Goody Ouchless Comfort Fit Headbands

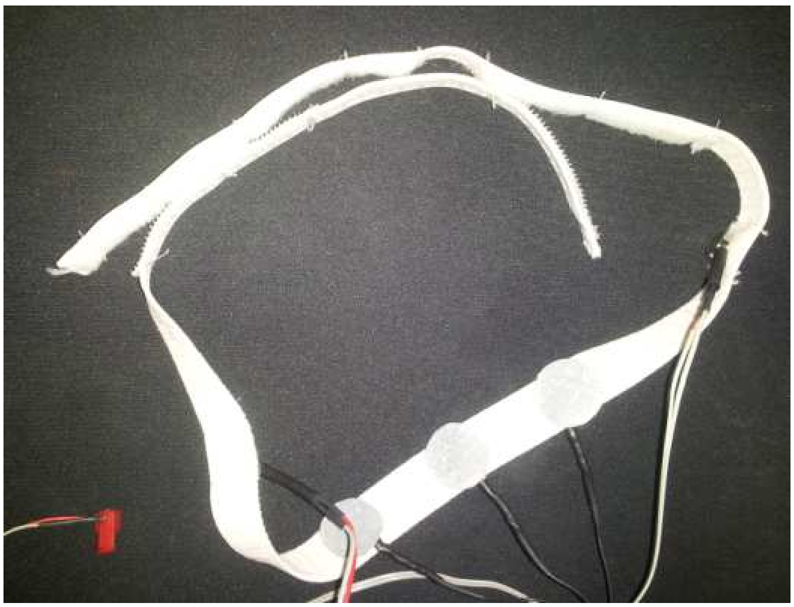
Advantages:

- Made of soft fabric for comfort
- Stretchy to fit a range of head sizes
- Machine washable
- Come in a variety of colors
- Possible enclosure for alerting device

Disadvantages:

- May not fit extremely large or small head sizes
- Could stretch out over time

Headband: White Velcro Band (Used in previous design)



Advantages:

- Adjustable for all head sizes
- Durable

Disadvantages:

- Material is itchy
- Hair could get caught in Velcro
- Uncomfortable for sleep

We chose the goody headbands to use in our design. The goody headbands are significantly more comfortable than the Velcro band, and fit a large range of head sizes. The user must be comfortable wearing this device in order to sleep and reach the REM stage. The goody headbands are inexpensive; they cost about 50 cents per headband. We are considering using the headband as a possible enclosure for our vibrator and or speaker. Since these headbands have 2 layers, they have the potential to enclose the components.

Electrodes: EEG Flat Sensors

Gold EEG Flat Sensor - 8mm flat gold disk style sensor terminated with a 1.5mm (.060) DIN safety plug.

Advantages:

- Guaranteed to pick up a decent signal

Disadvantages:

- Expensive
- Uncomfortable for use
-

Electrodes: Silver Knit Conductive Fabric

The fabric is 100% silver and highly conductive. It has a resistance of less than 1 ohm/foot in any direction across the textile.

Advantages:

- Less expensive than commercial electrodes
- Likely more comfortable than a disk electrode
- Able to choose size and shape

Disadvantages:

- Not guaranteed to pick up sufficient signal

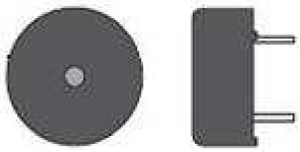
There are many types of EEG sensors on the market, but they are relatively expensive and push our cost constraints. The gold EEG sensor was $19.95, which was the cheapest commercial electrode we could find. The previous group actually made their own electrodes, which was virtually free. We want to improve on their sensors within cost constraints so we plan to make our electrodes out of silver fabric. We also found stainless steel conductive thread to help create our sensors. The silver fabric is relatively cheap compared to the commercial sensors, and should be more comfortable than the previous group's sensors.

Method of Alerting the User: Sound, Vibrations, or Light

Three main options were considered for the method of alerting and waking the user. We looked into using sound, vibration, light or a combination of the three to both alert the user when they are in a dream and to also wake the user once the dream state has ended. In order to gain a better understanding of the advantages and disadvantages of each method, we will examine each of the three options individually and the design challenges that each presents.

Method of Alerting: Sound (254-PB120-ROX)

The first option is using a piezoelectric speaker to audibly alert the user once they enter REM sleep with a tone soft enough to be heard while dreaming but not loud enough to wake the user up. The user would hear the tone inside their dream as a queue to allow for lucid dreaming. The same speaker would also be able to play a tone loud enough to wake the user after REM sleep is completed. This would allow the user to remember the dream they just had.



Advantages:

- Able to project both a sound quiet enough to alert and a sound loud enough to wake
- Low profile speakers are thinnest of the three options
- Moderately priced ($1.13)

Disadvantages:

- Hearing range varies by user
- The alert may not be picked up inside the dream

Method of Alerting: Vibrations

The second method is similar to the first. A coin vibration motor would be placed in the band and allow for two different strength of vibrations to accomplish the same two goals of queuing for lucid dreaming and waking the user through physical alerts.

Advantages:

- Coin motors are thin and would fit easily on the headband
- Multiple vibration intensities

Disadvantages:

- Most expensive of the three options (~$4.00)
- Slightly thicker than the speaker option
- May not be able to wake user

Method of Alerting: Light

The third option is with the use of LEDs. The LEDs would flash once the user enters REM sleep and give a visual queue in the user's dream to allow for lucid dreaming.

Advantages:

- A flashing light or color change would be an indicator the dreamer could easily notice inside their dream
- Cheapest of the three choices (~$0.30)

Disadvantages:

- Having to cover the eyes or have the LEDs hanging over the eyes would lower the comfort level of the device
- Unable to wake the user using only LEDs

We decided to use only sound to both alert the user they are dreaming as well as to wake the user. We made this decision as we wanted to keep the head harness as simple as possible without having to cover the eyes if we chose to use light as an indicator. We will only use one method to use as little battery as possible. If we find that the sound isn't able to successfully alert the user that they are currently in a dream we will add vibrations to our design.

Method of detecting REM sleep:

There are several ways of detecting REM sleep, some more practical than others when it comes to ease of use. We will look into detecting REM sleep through EEG, monitoring heart rate, and detection of eye movement.

Method of detection: EEG

This is the most commonly used and most direct way. Electrodes on the users scalp detect signals that correlate to eye movements to determine once REM sleep has been entered.

Advantages:

- Electrodes on the head are relatively invasive to allow the user a more comfortable sleep
- Detecting signals created by eye movement would be a clear indicator that the user is in REM (rapid eye movement) sleep

Disadvantages:

- Hair may interfere with signal detection
- May be uncomfortable to wear while sleeping

Method of Detection: Heart Rate

During the deeper stages of sleep the heart rate tends to slow down. A heart rate monitor could take readings while the user sleeps to determine when they are in REM sleep.

Advantages:

- Heart rates are easy to pick up and can be picked up from multiple party of the body
- Our group has already created a heart rate monitor in a previous project

Disadvantages:

- To determine when REM sleep is entered we must collect previous data to determine the user's heart rate trends during sleep
- Heart monitors may get in the way of the persons sleep and be uncomfortable to wear while sleeping

Method of Detection: Eye Movement

A final method is the detection of eye movement as again REM is an acronym for rapid eye movement. By shining an infrared signal on the eye and measuring the reflection, we would be able to detect eye movements associated with REM sleep.

Advantages:

- Detecting rapid eye movements is a clear indicator the user is in REM

Disadvantages:

- Infrared may harm the user's eye over time
- Having devices over the user's eyes can be uncomfortable

As we are continuing on with a previous project we will use the EEG method that has already been implemented.

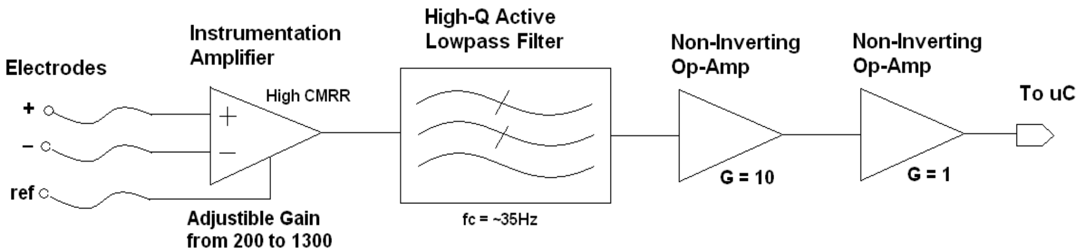
Method of Amplification: INA128 Instrumentation Amplifier

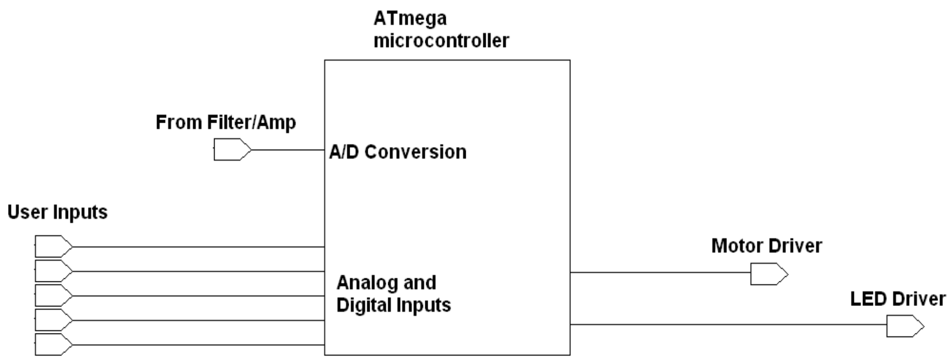
The previous group spent a great deal of time finding a sufficient instrumentation amplifier. They concluded that they needed an amplifier with a high CMRR of 120dB and high gain to amplify their signal. The INA128 is a small sized 3-op amp design with high gain, often used to amplify ECG/EEG signals. We plan on using the same amplifier in our design.

Method of Filtering: Common Low Pass Filter Design

There are commercial low pass filters available, but they are expensive and unnecessary for this project. The previous group used a common low pass filter in their design. Their filter was a 5^{th} order low pass filter with 35Hz cut of frequency. We will base our filter design on our electrode choice, and the signal they pick up.

Block Diagram:





Budget:

The purpose of this project is to create a REM sleep monitor that is cost efficient so anyone can recreate it. We want to share our design to benefit others, and allow them to experiment with the device. We plan on building one final PCB design, and three proto-boards on bread boards. The budget allows for 1 final design, 3 proto-boards, and 1 set of extra components.

Item	Part Number/Type	Cost/Unit	Quantity	Total Cost
ATmega328	-	$23	5	$115.00
Duracell Batteries	C1500B4N	$10	5	$50.00
Goody Headbands	-	$3.00	1	$3.00
Piezoelectric Speaker	254-PB120-ROX)	$1.13	5	$5.65
Silver Conductive Fabric	1167	$9.95	4	$39.80
Stainless Conductive Thread	603	$5.95	1	$5.95
Bluetooth Transmitter	-	$10.00	5	$50.00
Bluetooth Receiver (USB)	-	$5.00	5	$25.00
Miscellaneous components	-	$30	-	$30.00
PCB	-	$50	1	$50.00
3-D Printing	-	$10	1	$10.00
Total				**$384.40**

Summary:

In our conceptual design and options considered document we covered the previous work that the last group had completed. We also covered the previous work of commercial products, such as Lark Technologies, Innovative Sleep Solutions, Zeo and other lucid dream Induction devices. We discussed design options such as the micro controller, power source, headband, electrodes, methods of alerting the user, methods of detecting REM sleep, and the advantages and disadvantages for each design option. We provided a block diagram of how our system will operate. We also provided our expected budget of what we plan to spend on our design project. We believe we have the information needed to create a REM sleep monitor. We know what improvements we need to make on the hardware from last semester and what software we are going to be using. We are looking forward to constructing the REM sleep monitor and the possibility to use it for research.

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